COMPARISON OF DEDICATED AND MULTIPLE ACCESS-DISCRETE ADDRESS COMMUNICATIONS SYSTEMS

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THESIS

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and
Multiple Access-Discrete Address Communications Systems

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ABSTRACT

A comparison using analytic methods was made between a dedicated and a multiple access-discrete address communication system. The measure of effectiveness used was the probability that a message would be blocked from entering the system. Two types of blockages were identified (station busy, frequency busy). It was shown that if net messages are taken into consideration the advantages of a multiple access-discrete address communications system are not as great as have been previously reported.

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I. INTRODUCTION

A. BACKGROUND

In 1904 the first successful test of the radiotelephone (voice radio) was conducted. The subsequent introduction of radio telephones in the fleet brought about a great, if not immediate change in Naval communications. Prior to this change communication between ships was conducted at one battle control space which could have been called radio central. This centralization was necessary because personnel at other battle control spaces did not have a working knowledge of Morse Code or, in the case of radio telephones, remote control units did not exist. As technology advanced intership communications was no longer restricted to being between centralized spaces. Remote control stations, consisting of receiving outlets and transmitter keying positions, were located on the bridge, in the combat information center, and other battle control spaces where a need existed for direct intership communications. Receivers and transmitters, located in radio spaces, were connected to remote control positions as required.

The radiotelephone came to be considered one of the most useful military communications devices. Because of its directness, convenience, and ease of operation, voice radio was to be used almost exclusively between ships and between ships and aircraft for short-range tactical communications.

B. DEFINITION OF DEDICATED COMMUNICATIONS SYSTEM

Because there were different types of information to be exchanged between the various battle control spaces and if all the battle control spaces were grouped together the amount of transmissions might be so great that an important operational message might not be able to be sent, nets were introduced. A system of nets was constructed to connect directly the personnel who were delegated control of a specified function. A net connected a particular remote control station with the identical remote control station on the other ships in the task organization. There many times were more than one remote control station within a battle control space. For example, in a battle control space such as the combat information center, there has been a net designated as primary combat information (PRI-CI) for passing combat information between all units in the formation and another net called combat information and detection (CID) used for reporting combat information and detection.

The main point is that all nets were separate and each had its own frequency assigned. A station on ship A was not able to call another station on ship A. In addition, a station on ship A was not able to call any station other than the corresponding station on ship B.

Other restrictions existed under this system. No station was able to send and receive at the same time (half-duplex). If one station on a net was transmitting, all other stations on that net heard the transmission and were blocked from using the net.

The system of nets just described is basically that used in the fleet at the time of this study and was referred to as a dedicated

communications system. Dedicated, as used here implies that not only was one frequency assigned to any one net but that each net was used for the transfer of information related to a particular function.

C. DEFINITION OF MULTIPLE ACCESS-DISCRETE ADDRESS COMMUNICATIONS SYSTEM

It has been proposed that substantial improvements in intership communications could be realized by some form of integration of the many communication functions and their associated equipments. A communications system called multiple access-discrete address (MADA) has been advanced as meeting this proposal.

What is MADA? Multiple access means that the system will accept inputs from any of its stations at any time. The inputs are made directly as desired by the station, without prior authorization, multiplexing or other forms of organization. Discrete address means that each transmission is directed to a specific receiver or group of receivers as desired, setting up a private communication channel between transmitter and receiver. Each ship belonging to a MADA system would have a MADA control panel. The remote control units at each remote control station would be connected to their transmitters and receivers through this MADA control panel. The MADA control panel would monitor and store busy frequencies and what stations on which ships were using them.

How does a MADA system differ from a dedicated communication system? All nets are separate, however each net does not have its own frequency. The frequencies assigned to the MADA system are for the common use of any net. A station on ship A is still not able to call another station on ship A. In addition, a station on ship A is, as previously, not able to call any station other than the cor-

responding station on ship B. No station is able to send and receive at the same time. If one station on a net is transmitting to another station on that net, the other stations on the net in question would not hear the conversation and would not be blocked from transmitting unless they were trying to call an already busy station, or all the frequencies assigned to the system are busy. For example, if there were five frequencies assigned to the MADA system and there were ten stations per net, then it would be possible for five separate simultaneous conversations to be occuring on say PRI-CI. Of course no conversations would be able to take place on any other net, like the CID net, in the MADA system until one was finished on the PRI-CI net. It can be seen that, depending on the number of nets, the number of stations per net, and the number of frequencies assigned to the MADA system a large number of combinations of conversations exist.

In short, MADA may be described as a small telephone system. Terminals located in a ship would be connected to a switchboard. The switchboard would have access to line of sight transceivers, which are used to interconnect with other switchboards. Each station in a ship would have a unique telephone number. If it is desired to call another station in another ship, then the number is dialed. The switchboard would search for a non-busy frequency and finding one would interconnect with the switchboard of the called ship. The switchboard of the called ship would respond by ringing the appropriate station.

II. MODEL

The objective of this thesis was to determine potential applications of MADA communications systems to Naval systems. Navy tactical voice communications was the vehicle for a comparison between MADA and dedicated communications systems.

Previous comparisons between MADA and dedicated communications systems were reported by Janc, Marks and Thomopoulos [Ref. 3], Briat and Hauber [Ref. 4], and by Hauber and VanVliet [Ref. 5]. The results in this thesis were different than those used in Refs. 3-5.

Even though Ref. 3 states that it examined the possibility of a transaction being blocked because the station to be called was busy, no evidence that this event is actually included when arriving at any results was found. The importance of omitting this event from the comparison and its related effects on the results was significant.

References 4 and 5 allowed integration of nets under MADA. That is, it was possible for a station on ship A to call other than the corresponding station on ship B. This was analogous to allowing the bridge on ship A to call radio central on ship B. This integration of nets did not appear to be justified and only served to make MADA appear to be a substantially better system when compared to the dedicated system.

A queuing discipline of first come first served was used. This was decided upon because historically there have been no priorities assigned to transmissions on tactical nets.

If the station or stations called were busy then the calling station received a busy station indication and the transaction entered the calling queue. Once a transaction entered the calling queue it

remained there until the transaction could be completed. This was called a type I blockage. The probability of a type I blockage was designated as P(I).

If all frequencies were busy, then a calling station received a busy frequencies indication and that transaction went into the calling queue. This was called a type II blockage. The probability of this event was called P(II). It will be realized that under the dedicated system, whenever any transaction was in the system, a type II blockage occurred.

There was no processing time required by the MADA control panel and no station could send and receive at the same time.

The maximum number of frequencies which could be used by N stations of a net under the MADA system was N/2 when N was an even integer and (N-1)/2 when N was an odd integer. [1]Of course, for the dedicated system, the maximum usable number of frequencies for any net was one.

The number of stations in a net was greater than or equal to four. Three or less stations made a comparison between dedicated and MADA trivial.

There were three types of transactions or transmissions that could occur. These three types were a discrete, multiple, or net message. A discrete message was a transmission from one station to one other station in the net. A multiple message was a transmission from one station to a number of stations in the net, but not to all

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[1]Naval Electronics Laboratory Center Report 1616, Amphibious Warfare Communication System Configuration for 1975-1979 Era, by B.B. Briat and E.J. Hauber, pp. 33, 5 March 1969.

net stations. Multiple messages were assumed to be zero for the comparison. A net message is a transmission from one station to all stations in the net. Two separate cases were examined in regard to net messages. The first case assumed the number of net messages was zero. Using the results of a survey, which is detailed later, net messages were for the second case were assumed to be 46% of the total transmissions in the system. It made no difference to the dedicated system what percentage were net messages for any type of message presented a blockage to other transactions on that net.

Each net in the system had a poission message generation rate with mean L.

Message lengths were distributed exponentially with mean S. The average message length for each station of a net was the same and was S.

Each transaction by a station was independent of a transmission that was in the system.

III. ANALYSIS

A. INTRODUCTION

References 3-5 looked at the comparison of a best case analysis from the standpoint of MADA. The assumptions that made a best case analysis were no net messages, no multiple messages, and that each station had an equal desire to use the net (all L's equal). Not only did each station have an equal desire to use the net but called the other stations in the net with equal probability. Using a four ship task organization identified as A-D, this situation was described in Drawing one. The numbers along the line indicate the probability of that event occuring.

Using the situation of this best case analysis, the probability of a type I blockage for a net was computed.

Remembering that a type I blockage was defined as the event that if the station or stations called were busy, then the calling station received a busy station indication and the transaction entered the calling queue, the combinations where a type I blockage does not occur are listed below.

A calls B and (C calls D or D calls C)

A calls C and (B calls D or D calls B)

A calls D and (B calls C or C calls B)

B calls A and (C calls D or D calls C)

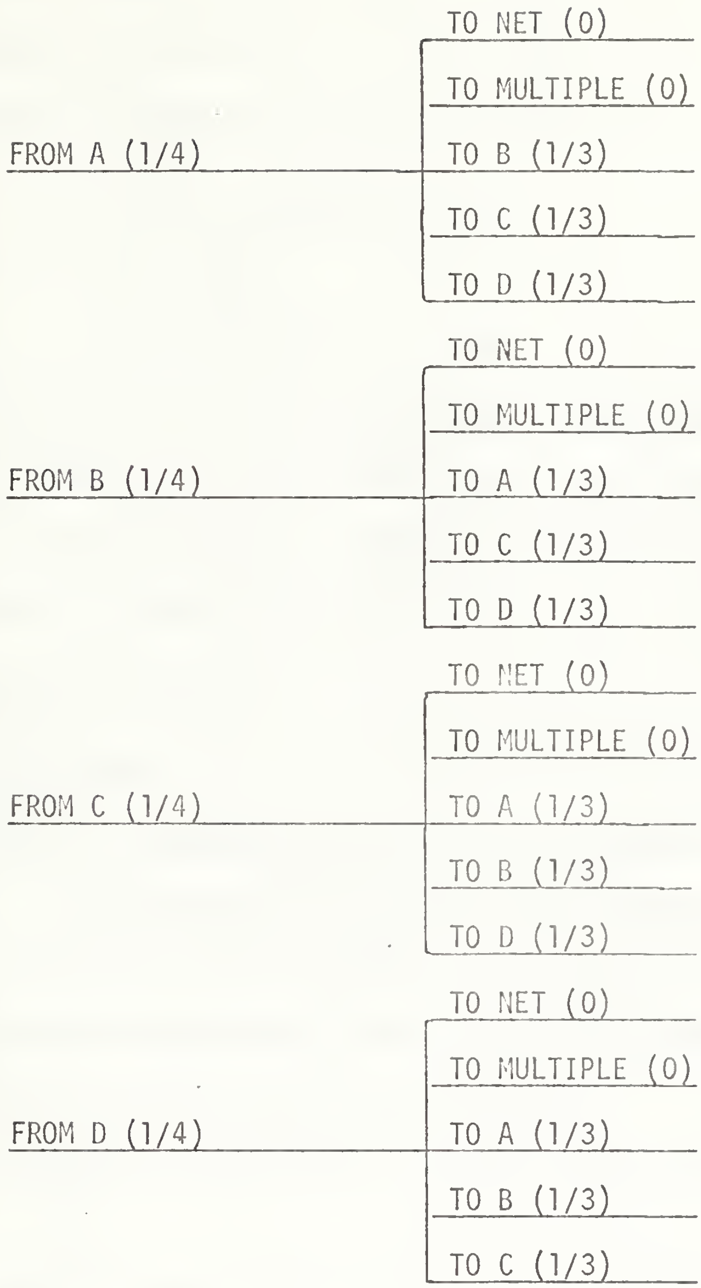
B calls C and (A calls D or D calls A)

B calls D and (A calls C or C calls A)

C calls A and (B calls D or D calls B)

C calls B and (A calls D or D calls A)

C calls D and (A calls B or B calls A)



DRAWING 1 -- BEST CASE DISTRIBUTION - FOUR STATIONS PER NET

D calls A and (B calls C or C calls B)

D calls B and (A calls C or C calls A)

D calls C and (B calls A or A calls B)

It will be noted that the twelve events,

A calls B	E1
A calls C	E2
.	
.	
.	
D calls C	E12,

formed a partition of the sample space; that is, the events were mutually exclusive and the probability of their union was 1. The number of ordered pairs was computed, using [n(n-1)=x], where n was the number of stations in a net.

B. PROBABILITY OF TIE UP

1. Best Case

Before computing the P(I) it was necessary to compute the probability of tie up which was called P(T). P(T) was the probability that a transaction could not enter the system because the station to be called was already busy. Given was the information that a transmission was already taking place on the net.

Using the combinations previously listed, P(T) can be expressed as,

$$\begin{aligned} P(T) = {} & P(\overline{E9 \cup E12} \mid E1)\,P(E1) + P(\overline{E6 \cup E11} \mid E2)\,P(E2) \\ & + P(\overline{E5 \cup E8} \mid E3)\,P(E3) + P(\overline{E9 \cup E12} \mid E4)\,P(E4) \\ & + P(\overline{E10 \cup E3} \mid E5)\,P(E5) + P(\overline{E2 \cup E7} \mid E6)\,P(E6) \\ & + P(\overline{E6 \cup E11} \mid E7)\,P(E7) + P(\overline{E10 \cup E3} \mid E8)\,P(E8) \\ & + P(\overline{E1 \cup E4} \mid E9)\,P(E9) + P(\overline{E5 \cup E8} \mid E10)\,P(E10) \\ & + P(\overline{E2 \cup E7} \mid E11)\,P(E11) + P(\overline{E1 \cup E4} \mid E12)\,P(E12). \end{aligned}$$

Concentrating on only the first part, we have

$P(\overline{E9 \cup E12}|E1)$ = probability that the transaction under consideration was not C calling D or D calling C when the transmission in the system was A calling B. Therefore, any of the other ten transactions was possible.

Using Bayes' theorem, this becomes

$$\frac{P[(\overline{E9 \cup E12}) \cap E1]}{P(E1)}$$

and since it was stated earlier that all transactions were independent of a transmission, this is equal to

$$P(\overline{E9 \cup E12}).$$

But by De Morgan's Laws, this is

$$P(\overline{E9} \cap \overline{E12})$$

which can be expressed as,

$$1-P(E9 \cup E12).$$

If E9 and E12 are any two events, then

$$1-P(E9 \cup E12) = 1-P(E9) - P(E12) + P(E9 \cap E12).$$

Since E9 and E12 were mutually exclusive

$$P(E9 \cap E12) = 0.$$

Therefore,

$$P[(\overline{E9} \cap \overline{E12})|E1] = 1-[P(E9) + P(E12)]$$

which was equal to the

$$P(T|E1).$$

Since the twelve events formed a partition of the sample space, P(T) was expressed as,

$$P(T) = \sum_{i=1}^{x} P(T|i)\ P(i)$$

where $x = n(n-1)$.

Of course, this formula was for a MADA system because the P(T) under a dedicated system was 1.

Using the best case analysis as expressed by Drawing 1, the numbers were:

$$P(T) = \sum_{i=1}^{12} (1/12)\ (10/12)$$

$$= .833.$$

2. Results of Survey

It was desirable to examine other than a best case. Because no data was readily available in the form needed, a survey of experienced Naval officers was conducted.

It must be realizedthat even if the data did exist, it would be of little help except that it would place a lower bound on the number of net messages. For example, what if a ship steaming in a task organization had a man overboard? Under the dedicated system the man on watch most likely would send his message to the officer in tactical command (OTC), knowing that all other stations in the net would monitor his transmission. However, using the MADA system the transmission should have been sent as a net message thereby increasing the number of net messages in a MADA system over that which would be reflected from fleet data. There were many more examples which could have been used. Under the MADA system, an increase in the number of net messages increased P(T).

A survey was conducted using 102 Naval officers, ranging in rank from Lieutenant to Captain. Twenty-seven of the subjects were stationed aboard ship in the San Diego area at the time of the survey. The remaining officers were students at the Naval Postgraduate School. The MADA system was first explained to them and they were allowed to

ask questions. For the type of questions that the answers were of the form, yes or no, the responses were paraphrased to fit categories. The questions and answers have been provided. It must be remembered that all questions were answered in the context of the MADA system.

1. What percentage of transmissions are originated by the OTC or someone like him?

sample mean ---------------- 60.24

sample standard deviation -- 6.31

2. Of the other transmissions would the remaining ships originate an equal amount of transmissions?

yes ------------------------ 82

no ------------------------- 8

do not know ---------------- 12

3. What percentage of those transmissions, originated by the OTC, would be net messages?

sample mean ---------------- 71.11

sample standard deviation -- 4.27

4. What percentage of those transmissions originated by another ship, would be to the OTC alone?

sample mean ---------------- 59.63

sample standard deviation -- 5.62

5. What percentage of those transmissions, originated by another ship, would be net messages?

sample mean ---------------- 10.02

sample standard deviation -- 1.73

6. You obviously had some particular number of ships in mind as you answered these questions. Do you think your answers would change as you increased or decreased the number of ships?

no -------------------------	63
yes, but not by much -------	28
yes ------------------------	6
do not know ----------------	5

The results of the survey were depicted for a four station net in Drawing 2. Station A is the OTC.

The probability of a tie up had to be extended for the case where the probability of a net message is not zero.

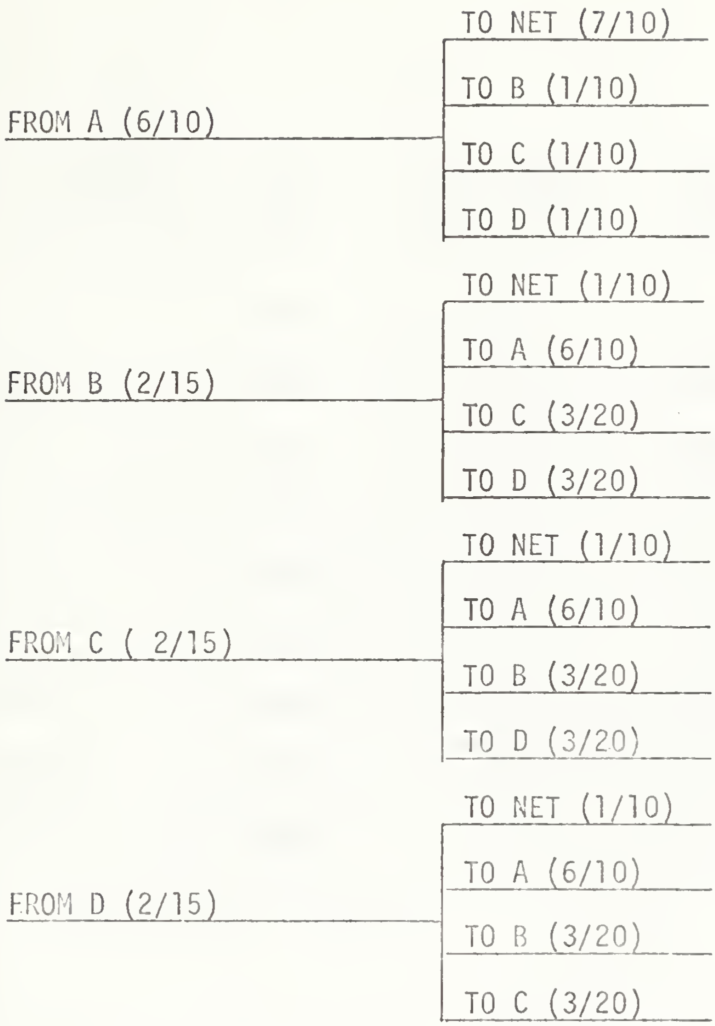
$$P(T) = \sum_{i=1}^{x} P(T|i)\ P(i) + P(\text{Net})$$

Using the distribution as expressed by Drawing 2, the numbers were:

$$\begin{aligned} P(T) &= 3(6/100)(576/600)+3(24/300)(576/600)+6(12/600)(258/300) \\ &\quad + P[\text{net}] \\ &= .506 + P[\text{net}] \\ &= .506 + (6/10)(7/10) + 3(4/30)(1/10) \\ &= .506 + .460 \\ &= .966 \end{aligned}$$

Using the same method, the P(T) for 5-12 stations per net was computed and was listed in Table I. As long as the number of transactions originated by the OTC, the number of net messages sent by the OTC, and the number of net messages sent to the OTC by other stations remained constant, then the probability of a net message was 46%, no matter how many stations per net. For this reason, probabilities computed using the results of the survey was referred to as MADA 46% NET.

It was realized that the P(T) as defined which was computed for six or more stations per net was less than the actual P(T) under



DRAWING 2 -- RESULTS OF SURVEY DISTRIBUTION-
FOUR STATIONS PER NET

NR. STATIONS PER NET	P(T) DED	P(T) MADA BEST CASE	P(T) MADA 46% NET
4	1.000	.833	.966
5	1.000	.700	.944
6	1.000	.600	.935
7	1.000	.524	.931
8	1.000	.464	.927
9	1.000	.417	.924
10	1.000	.377	.919
11	1.000	.345	.913
12	1.000	.318	.909

TABLE I. PROBABILITY OF TIE UP

the MADA system. In the case of six or seven stations per net to arrive at the true P(T) it would have been necessary to also compute the probability of a tie up, given that there were two transmissions in the system. It was understood that by leaving these additional probabilities out of the computations, the comparison would be biased in favor of the MADA system. However, the amount was not large.

C. PROBABILITY OF TYPE I BLOCKAGE

Since the event that led to a tie up, that is a transaction occurred while a transmission was in the system, did not occur with a probability of one, then the P(I) was less than P(T). It was thus necessary to find the probability that one or more transactions occurred while a transmission was in the system.

The assumption was made earlier that transactions were generated with a poisson distribution and that transmission time was exponentially distributed. For a Poisson process,

$$P(N(t) = j) = \frac{e^{-Lt}(Lt)^j}{j!} \quad [2]$$

What was of interest here was,

$$P(N(t) \geq 1),$$

which was equal to,

$$1 - P(N(t) = 0).$$

Substituting, this became,

$$1 - e^{-Lt}.$$

The random variable N was considered with respect to a time interval t equal in length to the mean transmission time, S. Therefore Lt was equal to LS which was the percent utilization.

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[2] PARZEN, E., Stochastic Processes, pp. 30, Holden-Day, 1967.

This made it possible to find P(I) without making any assumptions about the exact number for L or S. P(I) was looked at over a broad range of utilizations. Utilization as used here was the expected fraction of time the frequencies were busy.

Since this was a comparison between two systems, it was necessary to use the same input statistics. An example should illustrate this.

Example

Given:

mean transmission time (S) = 1/10 minute

four nets

message generation rate net 1 (L_1) = 2 per minute

message generation rate net 2 (L_2) = 3 per minute

message generation rate net 3 (L_3) = 3 per minute

message generation rate net 4 (L_4) = 4 per minute

Analysis:

$L = L_1 + L_2 + L_3 + L_4 = 12$

In the dedicated case,

$\bar{L}$ = L/number of nets

$= 12/4$

$= 3$

mean frequency utilization $= \bar{L}S$

$= 3(1/10)$

$= .3$

In the MADA case, frequency utilization = LS/m where m is the number of frequencies assigned to the MADA system.

$\bar{L} = L/m$

If $m = 4$, then

$\bar{L} = 12/4$

$= 3.$

Mean frequency utilization $= \bar{L}S$

$= 3(1/10)$

$= .3.$

In all of the tables that follow an implicit assumption was that for any utilization the number of frequencies assigned to the MADA system was equal to the number of nets in the dedicated system.

Since it was given once again that a transmission was in the system, the P(I) was an unconditioned probability. This was shown in the following manner.

Z was used to indicate a transmission was in the system.

$P(I) = P[(T|Z) \cap (N(t) \geq 1|Z)].$

Breaking this into components,

$P(T|Z) = \dfrac{P(T \cap Z)}{P(Z)}$.

Because of the independence of transactions and transmissions,

$P(T|Z) = P(T).$

Similarly,

$P(N(t) \geq 1|Z) = P(N(t) \geq 1).$

Therefore,

$P(I) = P[T \cap (N(t) \geq 1)].$

The probability that a transaction occurs was independent of whether or not that transaction experienced a tie up. Therefore,

$P(I) = P[(T) \cap (N(t) \geq 1)].$

Obviously, this formula was not used in computing P(I) for the dedicated system, but was just used for the MADA system. P(I) for a dedicated system was just equal to the utilization.

Tables II - X were computed for a large range of utilizations using from four to twelve stations per net.

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.041	.047
10	.100	.080	.092
15	.150	.116	.134
20	.200	.151	.175
25	.250	.184	.213
30	.300	.216	.250
35	.350	.246	.285
40	.400	.275	.319
45	.450	.302	.340
50	.500	.327	.380
55	.550	.352	.409
60	.600	.376	.436
65	.650	.398	.462
70	.700	.419	.486
75	.750	.440	.510
80	.800	.459	.532
85	.850	.477	.554
90	.900	.494	.573
95	.950	.519	.602
100	1.000	.526	.611

TABLE II. PROBABILITY OF TYPE I BLOCKAGE - FOUR STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.034	.046
10	.100	.067	.090
15	.150	.097	.131
20	.200	.128	.171
25	.250	.155	.209
30	.300	.181	.244
35	.350	.207	.278
40	.400	.231	.312
45	.450	.253	.342
50	.500	.275	.371
55	.550	.296	.399
60	.600	.316	.426
65	.650	.335	.451
70	.700	.352	.475
75	.750	.370	.498
80	.800	.386	.520
85	.850	.401	.541
90	.900	.415	.560
95	.950	.436	.588
100	1.000	.442	.597

TABLE III. PROBABILITY OF TYPE I BLOCKAGE - FIVE STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.029	.046
10	.100	.057	.089
15	.150	.083	.130
20	.200	.109	.169
25	.250	.133	.207
30	.300	.155	.242
35	.350	.177	.276
40	.400	.198	.309
45	.450	.217	.338
50	.500	.236	.367
55	.550	.254	.396
60	.600	.271	.422
65	.650	.287	.447
70	.700	.302	.470
75	.750	.317	.494
80	.800	.331	.515
85	.850	.344	.536
90	.900	.356	.554
95	.950	.374	.583
100	1.000	.379	.591

TABLE IV. PROBABILITY OF TYPE I BLOCKAGE - SIX STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.026	.046
10	.100	.050	.089
15	.150	.073	.129
20	.200	.095	.169
25	.250	.116	.206
30	.300	.136	.241
35	.350	.155	.275
40	.400	.173	.307
45	.450	.190	.337
50	.500	.206	.366
55	.550	.222	.394
60	.600	.236	.420
65	.650	.250	.445
70	.700	.264	.468
75	.750	.277	.492
80	.800	.289	.513
85	.850	.300	.533
90	.900	.311	.552
95	.950	.326	.580
100	1.000	.331	.588

TABLE V. PROBABILITY OF TYPE I BLOCKAGE - SEVEN STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.023	.045
10	.100	.044	.088
15	.150	.064	.129
20	.200	.084	.168
25	.250	.103	.205
30	.300	.120	.240
35	.350	.137	.273
40	.400	.153	.306
45	.450	.168	.336
50	.500	.182	.364
55	.550	.196	.392
60	.600	.209	.418
65	.650	.222	.443
70	.700	.233	.466
75	.750	.245	.489
80	.800	.256	.510
85	.850	.266	.531
90	.900	.275	.550
95	.950	.289	.578
100	1.000	.293	.586

TABLE VI. PROBABILITY OF TYPE I BLOCKAGE - EIGHT STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.020	.045
10	.100	.040	.088
15	.150	.058	.128
20	.200	.075	.167
25	.250	.092	.204
30	.300	.108	.239
35	.350	.123	.273
40	.400	.138	.305
45	.450	.151	.334
50	.500	.164	.363
55	.550	.176	.391
60	.600	.188	.417
65	.650	.199	.442
70	.700	.210	.465
75	.750	.220	.488
80	.800	.230	.509
85	.850	.239	.529
90	.900	.347	.548
95	.950	.260	.576
100	1.000	.264	.584

TABLE VII. PROBABILITY OF TYPE I BLOCKAGE - NINE STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.018	.045
10	.100	.036	.087
15	.150	.052	.128
20	.200	.068	.166
25	.250	.083	.203
30	.300	.098	.238
35	.350	.111	.271
40	.400	.124	.303
45	.450	.136	.333
50	.500	.148	.361
55	.550	.159	.389
60	.600	.170	.414
65	.650	.180	.439
70	.700	.190	.462
75	.750	.199	.485
80	.800	.207	.506
85	.850	.216	.526
90	.900	.224	.545
95	.950	.235	.573
100	1.000	.238	.581

TABLE VIII. PROBABILITY OF TYPE I BLOCKAGE - TEN STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.017	.045
10	.100	.033	.087
15	.150	.048	.127
20	.200	.062	.165
25	.250	.076	.202
30	.300	.089	.236
35	.350	.102	.269
40	.400	.114	.301
45	.450	.125	.331
50	.500	.136	.359
55	.550	.146	.386
60	.600	.156	.412
65	.650	.165	.436
70	.700	.174	.459
75	.750	.182	.482
80	.800	.190	.503
85	.850	.198	.523
90	.900	.205	.541
95	.950	.215	.569
100	1.000	.218	.577

TABLE IX. PROBABILITY OF TYPE I BLOCKAGE - ELEVEN STATIONS PER NET

MEAN UTIL PERCENT	P(I) DED	P(I) MADA BEST CASE	P(I) MADA 46% NET
5	.050	.016	.045
10	.100	.030	.086
15	.150	.044	.126
20	.200	.058	.165
25	.250	.070	.201
30	.300	.080	.235
35	.350	.094	.268
40	.400	.105	.300
45	.450	.115	.329
50	.500	.125	.357
55	.550	.135	.385
60	.600	.143	.410
65	.650	.152	.435
70	.700	.160	.457
75	.750	.168	.480
80	.800	.175	.501
85	.850	.182	.521
90	.900	.189	.539
95	.950	.198	.566
100	1.000	.201	.574

TABLE X. PROBABILITY OF TYPE I BLOCKAGE - TWELVE STATIONS PER NET

D. PROBABILITY OF TYPE II BLOCKAGE

P(II) was defined as the event that a transaction could not enter the system because all frequencies were busy.

For any particular utilization, the P(II) was the same, regardless of how many stations were on the net. Of course, for the MADA system, it made a difference how many frequencies were assigned. For the comparison, six frequencies were assumed to be in the MADA system. The proportion of transactions which find all frequencies busy and consequently wait until served has been previously computed.[3] Using these computations, the P(II) was placed in TABLE XI. It will be noted that for MADA it made no difference whether it was a best or 46% NET CASE.

E. PROBABILITY OF BLOCKAGE

The probability of blockage (P(B)) was the probability that a transaction experienced a blockage for any reason.

For the dedicated system, the P(B) was just the P(II).

The P(B) for the MADA system was not so straight forward, but almost as simple. Remembering that if a transaction had experienced a type II blockage, when a frequency became available it still might experience a type I blockage, a P(B) was computed.

$$P(B) = P(II) + P(\overline{II})\, P(I).$$

P(B) for the four station case appears in TABLE XII. It will be noted that the maximum percentage advantage for MADA appeared when the mean utilization was 55%. This same point of maximum advantage held for other numbers of stations per net and was exhibited in

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[3] Cooper, R.B., Introduction to Queueing Theory, Appendix A, Figure A.#., MacMillan, 1972.

MEAN UTIL PERCENT	P(II) DED	P(II) MADA
5	.050	.000
10	.100	.000
15	.150	.000
20	.200	.001
25	.250	.005
30	.300	.011
35	.350	.022
40	.400	.040
45	.450	.063
50	.500	.100
55	.550	.140
60	.600	.192
65	.650	.258
70	.700	.335
75	.750	.410
80	.800	.516
85	.850	.620
90	.900	.741
95	.950	.863
100	1.000	1.000

TABLE XI. PROBABILITY OF TYPE II BLOCKAGE

MEAN UTIL PERCENT	P(B) DED	P(B) MADA BEST CASE	P(B) MADA 46% NET
5	.050	.041	.047
10	.100	.080	.092
15	.150	.116	.134
20	.200	.152	.176
25	.250	.188	.217
30	.300	.225	.258
35	.350	.263	.300
40	.400	.304	.346
45	.450	.346	.391
50	.500	.394	.442
55	.550	.443	.492
60	.600	.496	.544
65	.650	.553	.601
70	.700	.614	.658
75	.750	.670	.711
80	.800	.738	.773
85	.850	.801	.831
90	.900	.869	.889
95	.950	.934	.946
100	1.000	1.000	1.000

TABLE XII. PROBABILITY OF BLOCKAGE - FOUR STATIONS PER NET

TABLE XIII. It will be noted that the maximum advantage (29.4%) was for the twelve stations per net best case situation. However, there were no net messages included in this case. For any percentage of net messages that was the percent of the MADA system that actually functioned as a dedicated system. For that reason when a reasonable percentage of net messages was considered the maximum advantage ran from 5.8% - 7.9%.

NUMBER STATIONS PER NET	P(B) DED	P(B) MADA BEST CASE	P(B) MADA 46% NET	ADVANTAGE MADA BEST CASE	ADVANTAGE MADA 46% NET
4	.550	.443	.492	.107	.058
5	.550	.395	.483	.155	.067
6	.550	.358	.481	.192	.069
7	.550	.331	.479	.219	.071
8	.550	.309	.477	.241	.073
9	.550	.291	.476	.259	.074
10	.550	.277	.475	.273	.075
11	.550	.266	.472	.284	.078
12	.550	.256	.471	.294	.079

TABLE XIII. ADVANTAGE MADA - 55% MEAN UTILIZATION

IV. CONCLUSION

A. COMMENTS

By virtue of the medium in which it operates and the necessity to maintain the coordinated operation of a number of separate operational units, the effectiveness of operations of a Naval force is directly related to the efficiency of its communications systems. In this light, research into all new improvements in these systems must be conducted in order that effectiveness is attained or maintained within cost limitations, in our Naval strike forces.

For this type of first look the concept of comparison with the existing system was considered valid and needed to be done. Also, the choice of MOE, probability of blockage, was believed good and valid as far as it went. Since this was not intended to be a "buy - no buy" comprehensive investigation, the multitude of questions raised would still have to be answered prior to any developmental efforts being started. For example, the sensitivity of this system to a certain percentage of non-MADA equipped units within the force, the system's ability to function in the event of a partial system failure, and the incidence of breakdown in the system. Finally, after all of those factors have been added in, an analysis giving the marginal cost per unit increase in efficiency of MADA in comparison with the existing system and with other current developments in communication would have to be completed. In addition, study would have to be made of the effect of the loss of "unintentional information transfer" caused by the incorporation of a multiple access-discrete address voice communications system.

It will be noted that another MOE, which is very important, was not examined. This MOE is average waiting time. Of course, this could have been looked at in this comparison. However, it would have required making an assumption about the average transmission time.

It was not deemed desirable to make this assumption. The latest voice traffic analysis study which the author had access to, which was based on over 600 hours of voice traffic, made the point that, "What is needed is accurate knowledge about the time parameters of individual circuits...."[4] It continued, "With such information, it would be possible to tackle the problems of re-structing nets, changing procedures selecting equipment, etc., to bring about improvements."[5] For these reasons, it was decided to use as the single MOE the probability of blockage for the way in which it was constructed, no time parameters had to be assumed.

B. ANOTHER LOOK

The analysis done by Dosher, Muckelrath and Sabeh [Ref. 11] presented another interesting approach to the probability of blockage. They defined a number of factors, two of which were:

(1) Percent Utilization (%U)

$$= \frac{T_t + T_o}{T_s} \qquad \text{and}$$

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4 Naval Electronics Laboratory Center Technical Document 175, Voice Traffic Analysis of Lantflex 66, Racer Run 68, and ROPEVAL 3-71 Exercises, by G. Dosher, P. Muckelrath, and Sabeh, pp. 11, 10 May 1972.

5 Ibid.

(2) Overhead rate (OR) = $\frac{To}{Ts}$

Where:

T_t was the time that operational information was exchanged during the sampling period. T_o was overhead time. Overhead time, "included circuit request, call-up radio checks, repeats, roger, and circuit release recorded during the sampling period."[6] T_s was the sampling period.

These factors or performance parameters when applied to ROPEVAL 3-71 where,

T_s = 130 hours

%U = .32

OR = 1.06

yielded

$$\frac{T_t + T_o}{T_s} = .32$$

$$\frac{T_o}{T_s} = 1.06.$$

Using T_s equal to 130 hours it was possible to solve for T_t and T_o. T_t was equal to 19.9 hours and T_o was equal to 21.7. It must be realized that here a "best case" analysis was also done, for in Racer Run the overhead rate was 1.93 and for Lantflex, the overhead rate was 1.53.[7]

If T_o was cut in half by some means, then percent utilization would drop from 32% to 23%. This would result in a decrease in

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[6] Ibid, pp. 6.

[7] Ibid, pp. 10.

P(B) for a dedicated system of .09. Referring to TABLE XII for the four stations per net case it can be seen that this is a larger decrease in the P(B) for 32% utilization than would be experienced by the MADA best case. It is also larger than the maximum advantage for MADA 46% NET listed in TABLE XIII.

The point of this section is to illustrate the fact that possibly more improvement of voice tactical communications could be gained by studying ways to correct the existing system, rather than by looking for a new system that will cure all ills.

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ABSTRACT

A comparison using analytic methods was made between a dedicated and a multiple access-discrete address communication system. The measure of effectiveness used was the probability that a message would be blocked from entering the system. Two types of blockages were identified (station busy, frequency busy). It was shown that if net messages are taken into consideration the advantages of a multiple access-discrete address communications system are not as great as have been previously reported.

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